Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

GERMINATION OF SEEDS OF WATER PLANTS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 104

WILLIAM CROCKER

Various botanists have noticed peculiarities in the germination of the seeds of water plants. MÜLLER[1] found that the seeds of Eichhornia and Heteranthera do not germinate without first being desiccated, and LUDWIG[2] demonstrated this for the seeds of *Mayaca fluviatilis*. In commenting upon this PFEFFER says:[3] "Nor is it certain whether BRAUN and MÜLLER are correct in assuming that previous drying is essential for the further development of Chlamydomonas or for the germination of the seeds mentioned." Dr. LAND, of this laboratory, informed me in the autumn of 1906 that he had made various attempts to secure seedlings of Sagittaria and Alisma for class use, but had always failed except in one trial with Sagittaria. In that case a number of seeds grew after being left for a long period on wet soil in a hot greenhouse. At that time I began looking into the cause for the failure to germinate and had arrived at the main conclusion of this paper when an article by FISCHER[4] appeared on the subject.

The main points of FISCHER's paper may be stated briefly: The seeds of *Alisma Plantago*, *Potamogeton lucens*, *P. pectinatus*, *Hippurus vulgaris*, *Polygonum amphibium*, *Scirpus lacustris*, *S. maritimus*, *Sagittaria platyphylla*, *S. sagittifolia*, and *Sparganium ramosum* may be kept for years in water that is free from fermentation without germinating. If fermentation is set up in the water, germination soon begins. Germination can also be brought about, especially in Sagittaria, by subjecting the seeds to the action of bases and acids. FISCHER holds that the H^+ or OH^- ions act as stimulants on the dormant protoplasm of the embryo, arousing it to growth. He holds that the action is not on the coats, and adduces as evidence the facts that the seed coats are permeable to both water and compounds dissolved in it, and that a disorganization of the coats is brought about only by long exposure to such agents as concentrated H_2SO_4. He believes that the weak acids and bases used as stimuli could have no effect on the coats, and that in nature the germination is brought about by acid, formed in the decay of organic matter in ponds, which acts upon the dormant protoplasm.

---

[1] See LUDWIG's article below.

[2] LUDWIG, F., Ueber durch Austrocknen bedingte Keimfähigkeit der Samen einiger Wasserpflanzen. Biol. Centralbl. **6**:299, 300. 1886.

[3] PFEFFER, W., Physiology of plants (Eng. ed.) **2**:210. 1903.

[4] FISCHER, ALFRED, Wassertoff- und Hydroxylionen als Keimungsreize. Ber. Deutsch. Bot. Gesells. **15**:108–122. 1907.

I find that FISCHER is entirely wrong in assuming, first, that the protoplasm of these seeds is in a dormant stage; and, second, that a chemical stimulus is necessary to bring about germination. Likewise MÜLLER is wrong in assuming desiccation to be necessary for the germination of the seeds of Eichhornia. I find that the embryos of all seeds of water plants I have tested begin germination very readily when the ordinary conditions for germination are furnished them, and especially the one condition of sufficient water supply. In an article already published,[5] I have shown that cases of delayed germination or entire failure to germinate are generally related to the character of structures inclosing the embryo and not to dormancy of its protoplasm. In the paper cited I mention certain species of Iris that germinate only when the cap covering the embryo is removed, although the structures are permeable to water and the embryo imbibes water until it entirely fills the cavity it occupies. The water thus admitted is not sufficient to start growth, and the embryo lies in this semi-saturated condition. It is only when the limits to water absorption are removed that growth begins. Exactly the same thing occurs with the seeds mentioned by MÜLLER and FISCHER. Before discussing this point farther some facts about the ripening and harvesting of the seeds mentioned in the table below must be stated.

The seeds of Alisma, Sagittaria, and Typha all ripen above water, while those of Eichhornia and Potamogeton ripen under water, as do the seeds of many other water plants. The ripening under water is brought about by the flower stalks responding positively to gravity soon after fertilization. A large number of Eichhornia seed stalks were gathered on October 1, while yet green, from one of the lagoons of Washington Park. Some of the green seeds were removed from the capsules and placed in distilled water, which was changed twice a day and kept at 23°C. Within a week twenty per cent. had germinated. A portion of the seed stalks were placed in distilled water repeatedly changed and kept at 23°C. Many of these seeds germinated while yet green and in the capsules. Still other seed stalks were kept in distilled water in an ice-chest at 6°C. None of these seeds germinated, but after three weeks many had ripened, as indicated by the hard brown coats. When the seeds with mature coats were kept at either 23° or 29° none germinated. Likewise seeds of *Potamogeton natans* and *P. pectinatus*, when gathered green and put into distilled water at 23° C. which was repeatedly changed, gave a considerable percentage of germination, while seeds allowed to ripen in the cold water of the ponds and then kept at 23° or 29° did not germinate.

---

[5] CROCKER, WM., Rôle of seed coats in delayed germination. BOT. GAZETTE 42:265–291. 1906.

If the real conditions demanded for the germination of the embryos of these seeds are to be determined, the embryos must be freed from any possible effect of the coats by carefully rupturing them without injuring the embryos. An experiment, the results of which are embodied in the accompanying table, shows conclusively the effect of the coats on germination, as well as the true condition of the embryos as to dormancy. Ripe seeds were used in this experiment. To guard against any possibility of acid formation by fermentation, the seeds of Potamogeton were entirely freed from the fleshy material surrounding the hard seed coat, all were sterilized in five per cent. formalin for eight minutes, and then washed thoroughly in sterilized distilled water. The coats of one-half the seeds of each species were broken, with sterilized instruments, at the point where the cotyledons naturally emerge from the coats. This is a very tedious process, because the seeds are so small (especially those of Sagittaria, Typha, and Alisma), and because great care must be taken not to injure the embryos. After this treatment the seeds were put into sterilized distilled water and placed in a bath at 29°C. During the first two days they were kept in total darkness and after that in diffuse light. Within an hour after the coats were broken the cotyledons projected considerably, on account of the rapid imbibition of water. In one day germination was well started, as shown by the length of the cotyledons and their response to gravity. In two days the growth was very marked.

It might be urged that breaking the coats leads to increased oxygen supply and for that reason brings about germination. This is not at all probable for two reasons: first, increased oxygen pressures never bring about germination when the coats are intact; and second, these seeds require very little oxygen for germination. If the coats are ruptured, they will germinate if placed in water that has been previously boiled and covered with liquid paraffin. That the coats hinder germination by limiting the water supply is made evident by the fact that the cotyledon begins to project beyond the coat very soon after the latter is ruptured. In this experiment it seems impossible to justify the assumption that the protoplasm is in a dormant state or that the application of any external ions are necessary to start germination.

It is of interest to determine what structures surrounding the embryos limit the water absorption. In Sagittaria and Alisma there is an outer husklike exocarp and an inner hard endocarp. The removal of the exocarp did not increase the per cent. of germination, provided the endocarp was not injured in its removal. In Eichhornia the embryo is surrounded by a rather thick endosperm which is covered by a hard, fluted, brown seed coat. If the coat is broken at the side, it leads to a rather slow germination of over 50 per cent. of the seeds. If the coats are ruptured where the cotyledons naturally push out and where they lie very near the coats, nearly 100 per cent. germinate with remarkable promptness. This leads one to conclude that the hard coat chiefly limits water absorption, but that the endosperm too retards it. In the Potamogetons it is the hard stony coat that limits water absorption.

If the seeds of Sagittaria or Alisma are run through a coffee mill, set rather close, and are then placed in water, a large per cent. will grow. This breaks the seed coats without a very marked injury to the embryos. These seeds will also germinate after considerable time if planted in rich humus that is decaying by reason of abundant moisture and high temperature.

In the light of the work of MÜLLER and FISCHER two questions

SPECIES	CONDITION OF COATS	AFTER 1 DAY		AFTER 2 DAYS		AFTER 10 DAYS	
		Per cent. of germ.	Length of plantlets in mm.	Per cent. of germ.	Length of plantlets in mm.	Per cent. of germ.	Size of plantlets
Alisma Plantago........	Entire	0		0		0	
	Ruptured	86	2–3	86	3–7	98	2 leaves
Eichhornia............	Entire	0		0		0	
	Ruptured	96	2–4	98	4–7	98	2 leaves
Polygonum amphibium..	Entire	0		0		0	
	Ruptured	81	2–3	85	4–7	85	20–25$^{\mathrm{mm}}$
Potamogeton natans*...	Entire	0		0		0	
	Ruptured	42	3–5	51	5–8	51	20–30$^{\mathrm{mm}}$
Potamogeton pectinatus*	Entire	0		0		0	
	Ruptured	47	2–4	53	4–7	53	12–16$^{\mathrm{mm}}$
Sagittaria variabilis.....	Entire	0		0		0	
	Ruptured	92	2–3	92	4–7	92	2 leaves
Typha latifolia.........	Entire	0		0		0	
	Ruptured	85	2–4	89	4–8	89	2 leaves

* The low percentage of germination here is due to many of the seeds having no embryos.

demand answer. How does a period of desiccation bring about the germination of the seeds of Eichhornia as shown by MÜLLER, or of Potamogeton as shown by FISCHER? What was the rôle of the bases and acids in FISCHER'S experiments? My experiments indicate that drying followed by soaking causes a considerable per cent. of the coats of Eichhornia to crack along the flutings, while it causes the rupture of the coats of Potamogeton along two creases that lie at the convex side of the embryo. Just how the bases and acids work has not yet been determined. That FISCHER is wrong in assuming that they arouse the dormant protoplasm is evident, for I have shown that the embryos respond to ordinary germinative conditions almost, if not quite, as readily as any embryos to be found. The action that causes the germination must evidently be upon the structures surrounding the embryos. That H^+ and OH^- ions, as well as many others, may increase somewhat the rate of growth of the naturally rapid-growing embryos, is not at all improbable. The fact that the coats showed no visible change when treated with acids and bases does not indicate that the coats were not radically changed. I have found that the impermeable coats of many of the seeds of the Leguminosae are made permeable by soaking them in absolute alcohol, and yet no change visible with the microscope appears. Experiments are being conducted now to determine the exact effect of acids and bases upon the seed coats and embryos of these seeds, as well as to determine in detail various other points connected with this problem.

I wish to emphasize again, as I have done already in the paper cited, the fact that delayed germination or failure to germinate is more generally due to seed-coat effects (limiting or entirely excluding water or oxygen supply) than to embryo characters, as has generally been assumed. On the other hand, in the same paper, I have shown that the failure of the seeds of hawthorns to grow under ordinary germinative conditions is due to embryo characters, and I have further stated that other seeds probably belong to this category. If seed coats play such an important part in failure to germinate, it is probable that spore coats act similarly in many cases. This hypothesis is now being tested.

THE UNIVERSITY OF CHICAGO